

Cosmochemistry of the Early Solar Nebula

Ross Taylor

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The Australian National University**



Harold Clayton Urey 1893-1981

Cosmochemical Periodic Table of the Elements in the Solar System

2.43e10 H																	2.343e9 He				
55.47 Li 1.142e	0.7374 Be 1.84e-5	<div><div>abund.</div><div>EL</div><div>Tc (K)</div><div>box color:</div><div>refractory</div><div>intermediate</div><div>volatile</div><div>chalcophile</div><div>s=solid solution</div><div>refractory</div><div>common</div><div>volatile</div><div>highly volatile</div></div>														17.32 B 1.84e-5	7.079e6 C 40	1.950e6 N 123	1.413e7 O 140	841.1 F 1.34e-5	2.148e6 Ne 9.1
57510 Na 9.54e-5	1.000e6 Mg 1336															84100 Al 1.25e-5	1.000e6 Si 1310	8373 P 1225	444900 S 954	5237 Cl 1.45e-5	102500 Ar 47
3693 K 1.000e-5	62670 Ca 15.17	34.20 Sc 1.55e-5	2422 Ti 1.58e-5	266.4 V 1.42e-5	12600 Cr 1296e-5	9168 Mn 1.15e-5	836000 Fe 1334	2323 Co 1.35e-5	47600 Ni 1.55e-5	527 Cu 1.007e-5	1226 Zn 7.25e-5	35.97 Ga 9.88e-5	120.6 Ge 8.83e-5	6.089 As 1.0e-5	65.79 Se 6.97e-5	11.32 Br 1.4e-5	55.15 Kr 52				
6.572 Rb 8.01e-5	23.64 Sr 1.464e-5	4.608 Y 1.65e-5	11.33 Zr 1.74e-5	0.7554 Nb 1.55e-5	2.601 Mo 1.59e-5	Tc	1.900 Ru 1.56e-5	0.3708 Rh 1.35e-5	1.435 Pd 1.32e-5	0.4813 Ag 9.90e-5	1.584 Cd 0.52e-5	0.1810 In 5.30e-5	3.733 Sn 7.04e-5	0.3292 Sb 1.73e-5	4.815 Te 7.05e-5	0.9575 I 5.35e-5	5.391 Xe 53				
0.3671 Cs 1.0e-5	4.351 Ba 1.45e-5	0.4405 La 7.97e-5	0.1899 Hf 1.66e-5	0.02099 Ta 1.2e-5	0.1277 W 1.76e-5	0.05254 Re 1.62e-5	0.6738 Os 1.61e-5	0.6448 Ir 1.60e-5	1.357 Pt 1.40e-5	0.1955 Au 1.05e-5	0.4128 Hg 2.57e-5	0.1845 Tl 5.32e-5	3.258 Pb 7.27e-5	0.1388 Bi 7.48e-5	Po	At	Rn				
Fr	Ra	Ac	Rf	Ha	106	107	108	109	110	111	112										
K. Lodders, 2003, Solar System Abundances and Condensation Temperatures of the Elements, Astrophys. J 591, 1226-1247					1.169 Ce 1.47e-5	0.1737 Pr 1.55e-5	0.6355 Nd 1.63e-5	Pm	0.2542 Sm 1.52e-5	0.09513 Eu 1.35e-5	0.3321 Gd 1.53e-5	0.05907 Tb 1.05e-5	0.3862 Dy 1.53e-5	0.08986 Ho 1.63e-5	0.2554 Er 1.53e-5	0.0370 Tm 1.63e-5	0.2484 Yb 1.63e-5	0.03572 Lu 1.63e-5			
					0.03512 Th 1.63e-5	Pa	9.31e-3 U 1.63e-5	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr			

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Refractory



Intermediate



Volatile

Cosmochemical Periodic Table of the Elements in the Solar System																		2.343e9 He
2.43e10 H																		
55.47 Li 1.142 s	0.7374 Be 1.622 s	<div>abund. EL Tc (K)</div> <div>box color:</div> <div>chalcophile siderophile astrophile</div> <div>S = 1e6 atoms element symbol 50% condensation temperature at 1e-4 bar s=solid solution</div> <div>refractory common volatile highly volatile</div>										17.32 B 928 s	7.079e6 C 40	1.950e6 N 123	1.413e7 O 180	841.1 F 734 s	2.148e6 Ne 2.1	
57510 Na 258 s	1.020e6 Mg 1336											84100 Al 195 s	1.000e6 Si 1310	8373 P 1229	444900 S 664	5237 Cl 948 s	102500 Ar 47	
3992 K 1008 s	62870 Ca 18.17	34.20 Sc 7893 s	2422 Ti 1340	288.4 V 1408 s	12960 Cr 1296 s	9168 Mn 1198 s	838000 Fe 1334	2323 Co 1352 s	47800 Ni 1353 s	527 Cu 1037 s	1226 Zn 725 s	35.97 Ga 958 s	120.6 Ge 683 s	6.089 As 1065 s	65.79 Se 697 s	11.32 Br 546 s	55.15 Kr 57	
6.572 Rb 803 s	23.64 Sr 1964 s	4.608 Y 1652 s	11.33 Zr 1743	0.7554 Nb 1876 s	2.601 Mo 1590 s	Tc	1.900 Ru 1561 s	0.3708 Rh 1392 s	1.435 Pd 1324 s	0.4913 Ag 998 s	1.584 Cd 652 s	0.1810 In 536 s	3.733 Sn 704 s	0.3292 Sb 979 s	4.815 Te 709 s	0.9975 I 535 s	5.391 Xe 58	
0.3671 Cs 798 s	4.351 Ba 1426 s	0.4405 La 1525 s	0.1699 Hf 1564 s	0.02009 Ta 1872 s	0.1277 W 1789 s	0.05254 Re 1821 s	0.6738 Os 1812 s	0.6448 Ir 1603 s	1.357 Pt 1408 s	0.1955 Au 1050 s	0.4128 Hg 252 s	0.1845 Tl 532 s	3.258 Pb 727 s	0.1388 Bi 746 s	Po	At	Rn	
Fr	Ra	Ac	Rf	Ha	106	107	108	109	110	111	112							
K. Lodders, 2003, Solar System Abundances and Condensation Temperatures of the Elements, <i>Astrophys. J</i> 591, 1220-1247			1.169 Ce 1476 s	0.1737 Pr 1382 s	0.8355 Nd 1603 s	Pm	0.2542 Sm 1390 s	0.09513 Eu 1356 s	0.3321 Gd 1039 s	0.05907 Tb 1053 s	0.3862 Dy 9129 s	0.08065 Ho 1063 s	0.2554 Er 1659 s	0.0370 Tm 1350 s	0.2484 Yb 1497 s	0.03572 Lu 1352 s		
			0.03512 Th 1405 s	Pa	9.31e-3 U 1410 s	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

(c) K. Lodders

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Lithophile

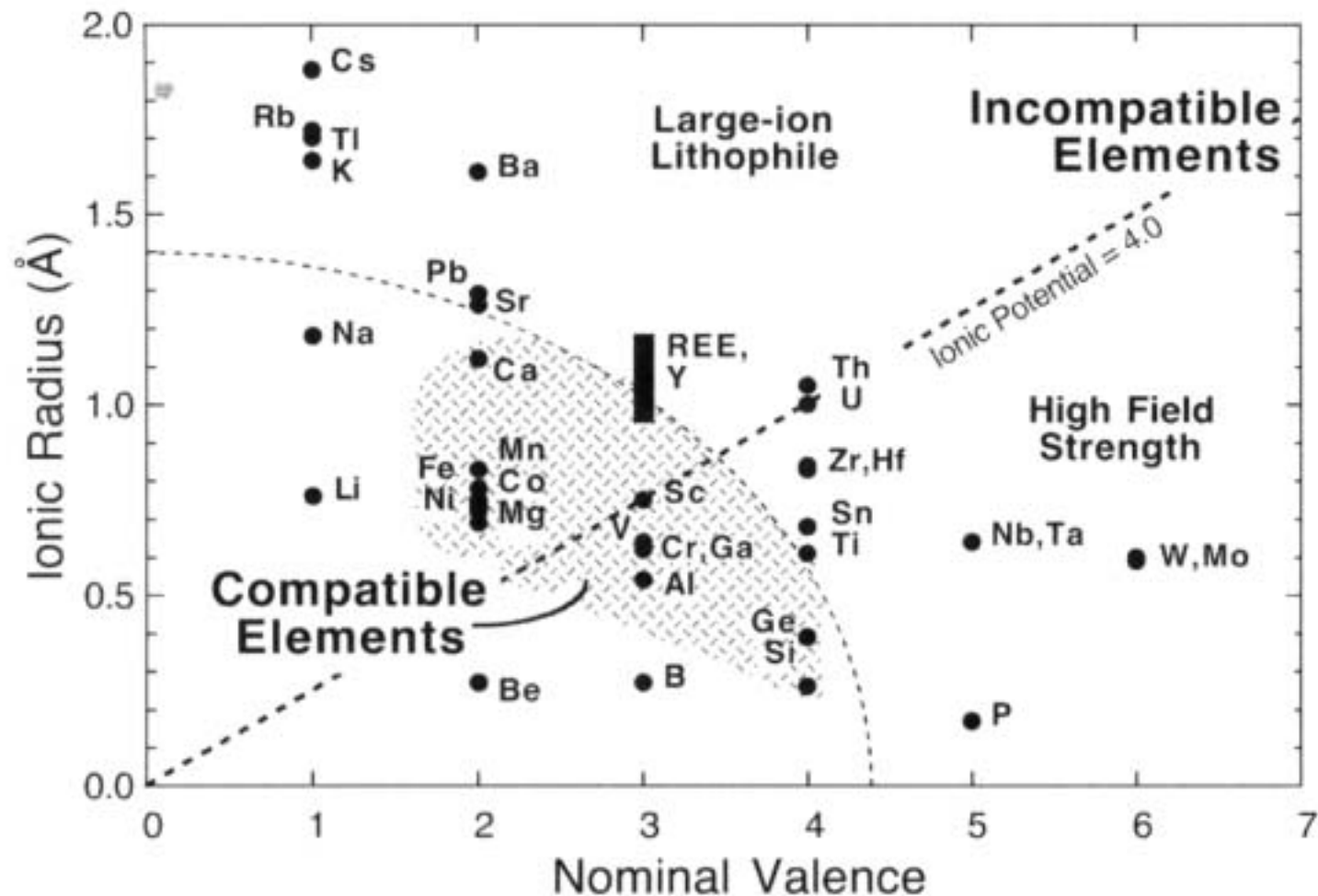


Siderophile

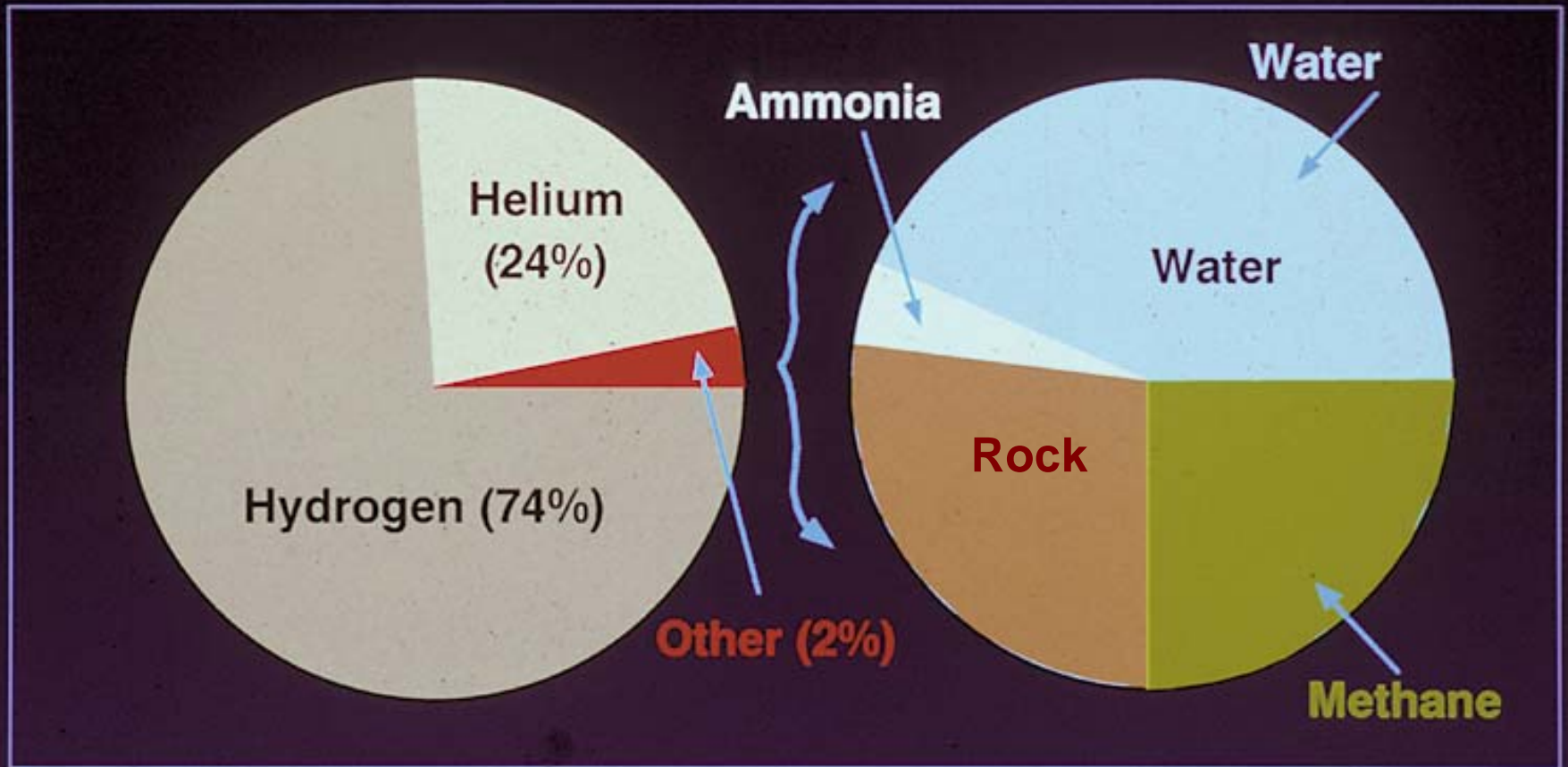


Chalcophile

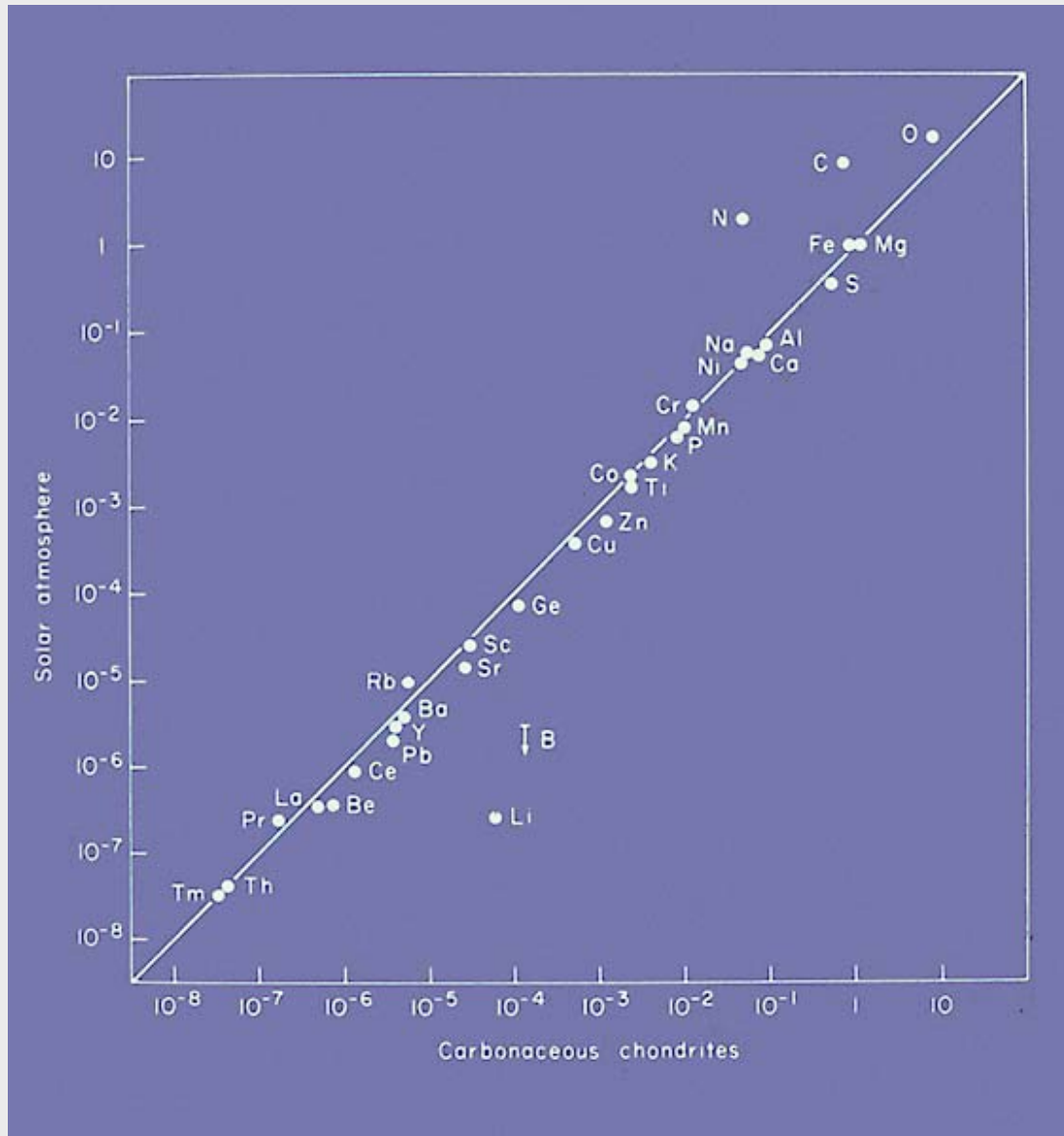
Lithophile element distribution in silicates

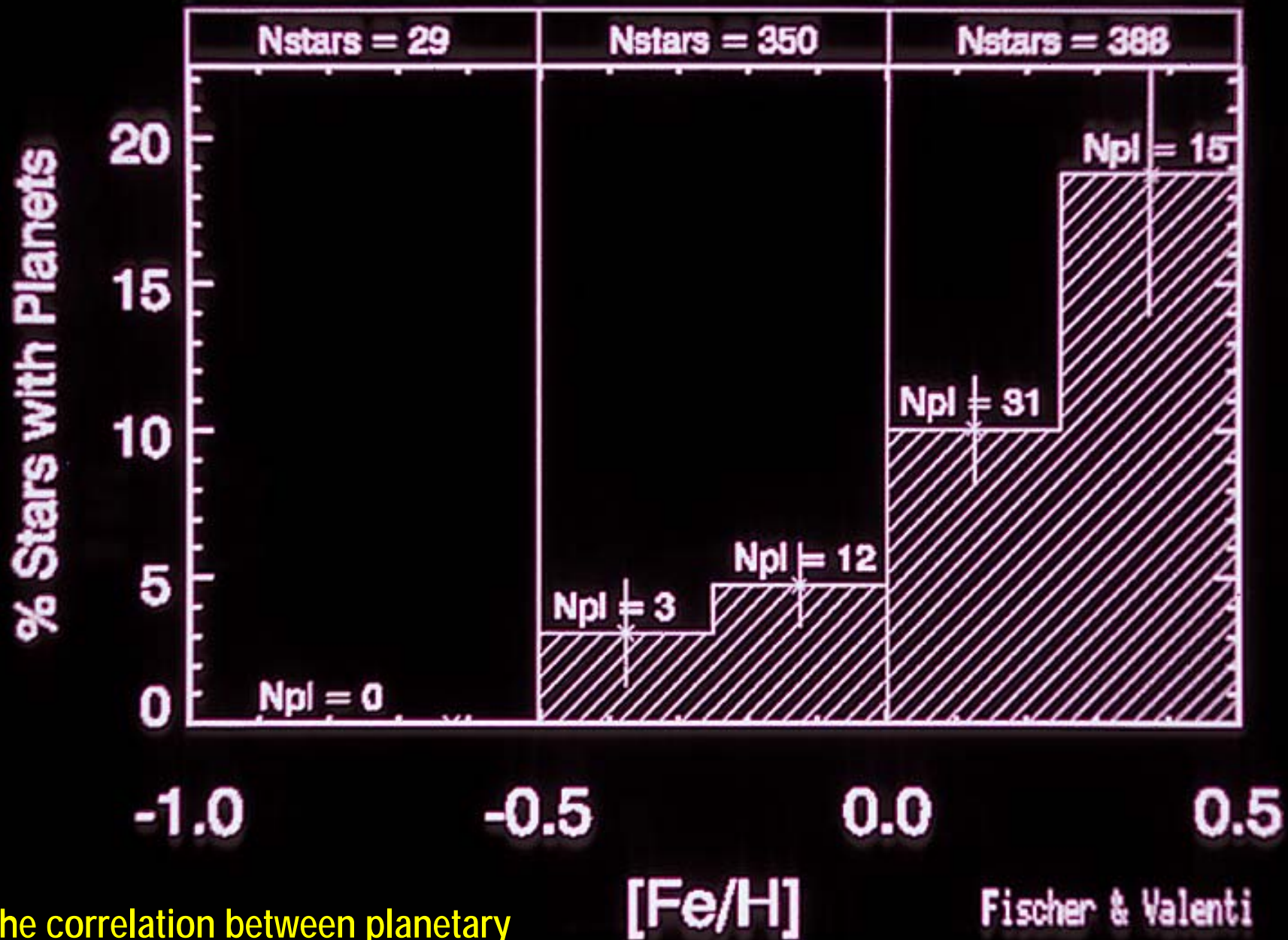


Gas, ice and rock fractions in primordial nebula



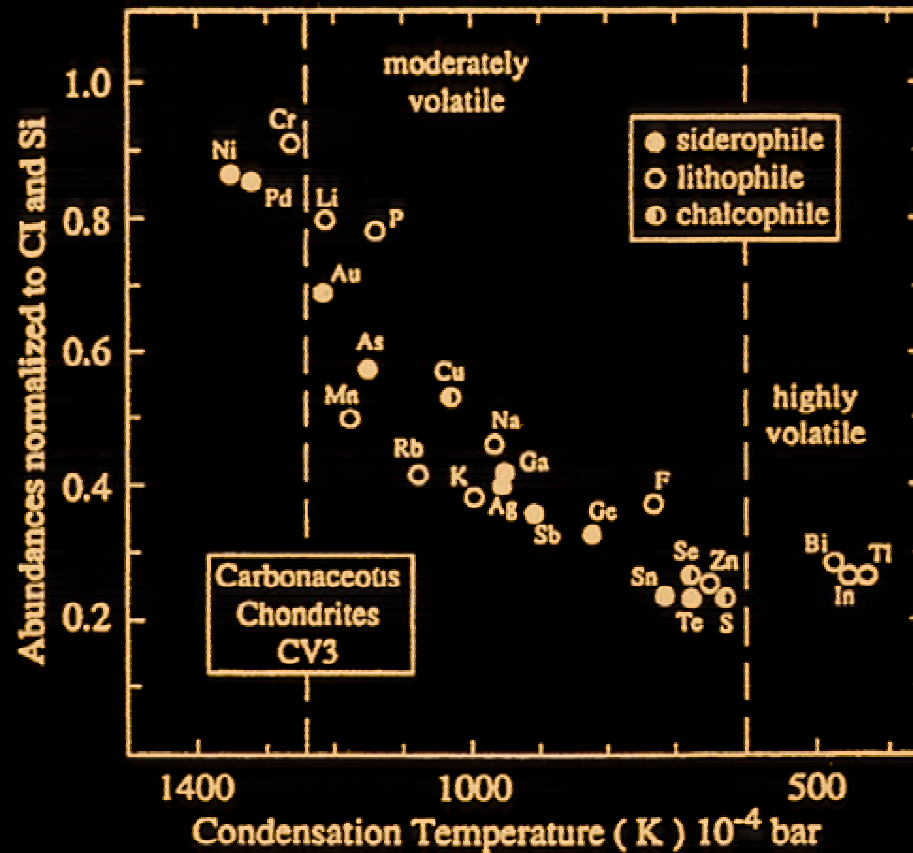
Elemental abundances, relative to Si, in the solar photosphere and in CI meteorites



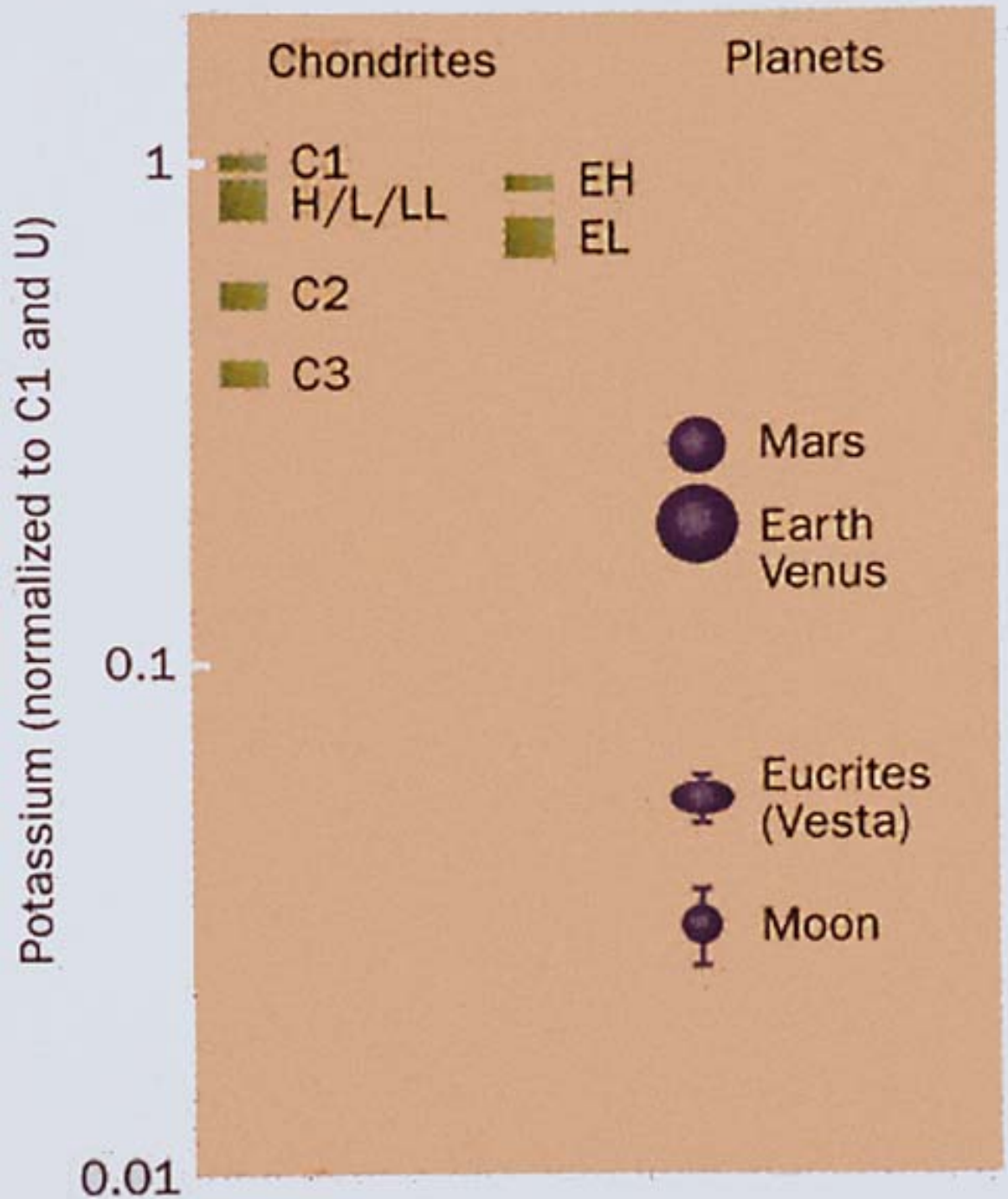


The correlation between planetary abundances and metal rich stars

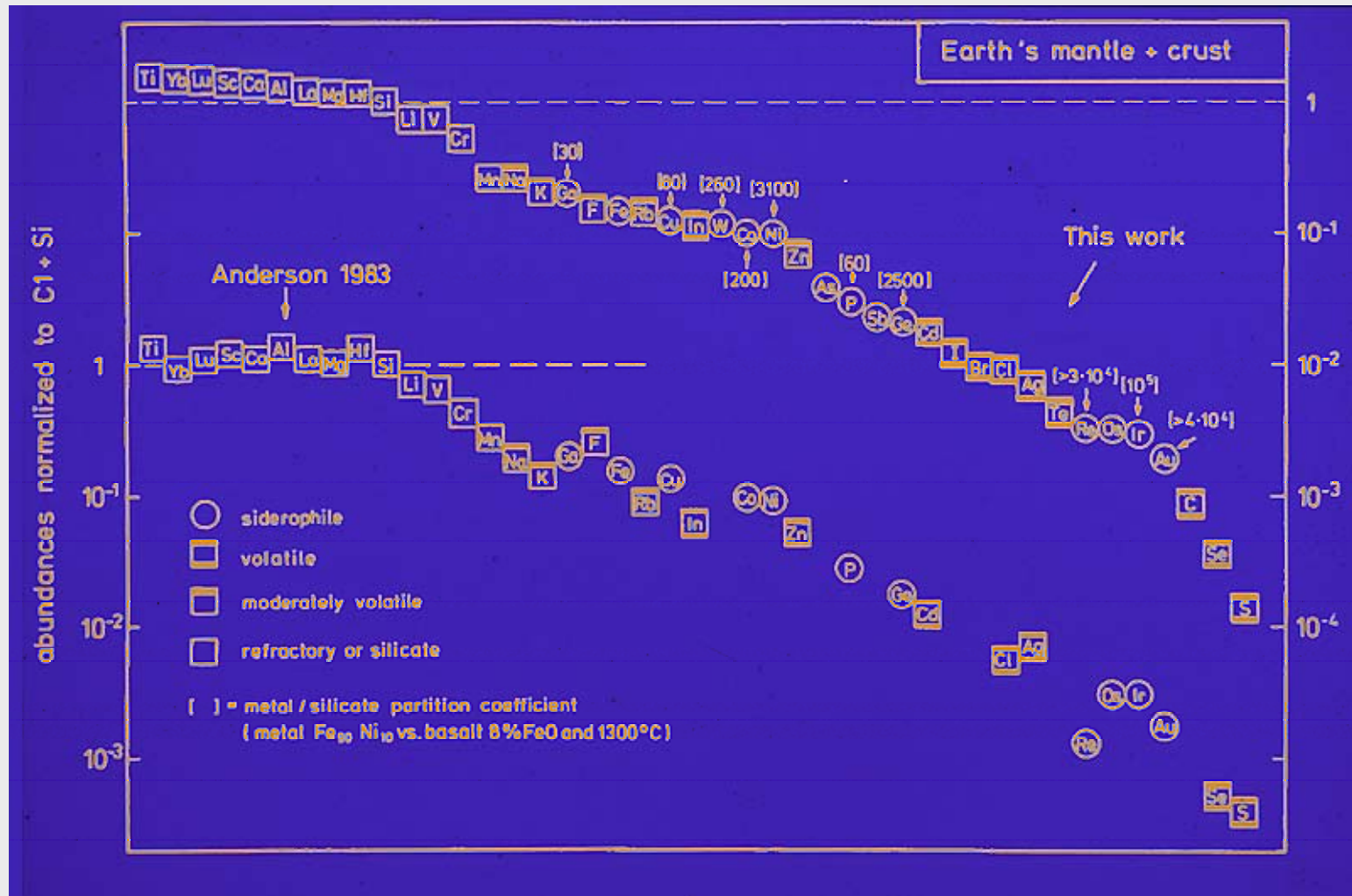
Element depletion in CV3 meteorites, relative to CI, correlates with volatility (Palme)



Depletion of volatile
potassium relative to
refractory uranium in
the inner solar system
(Humayun)

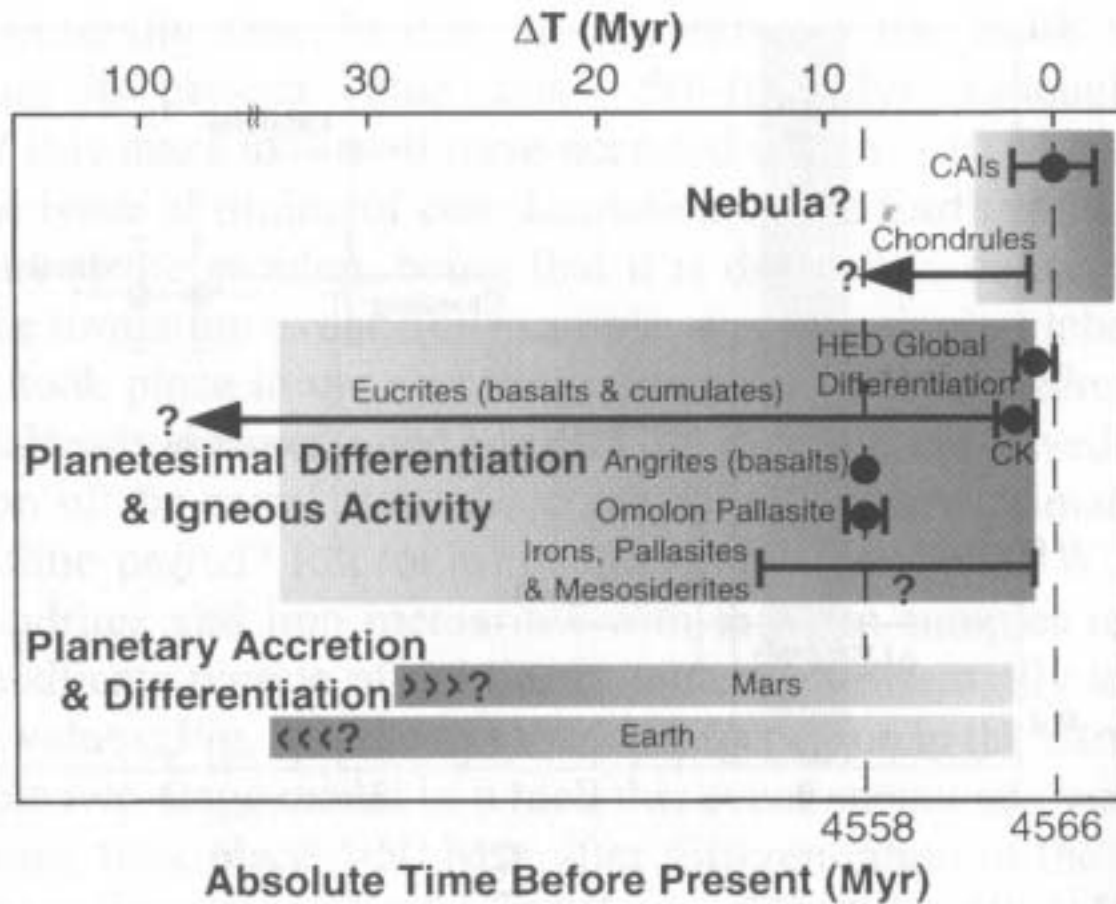


Elemental depletions, relative to Cl, in the Earth correlate with volatility (Wänke)

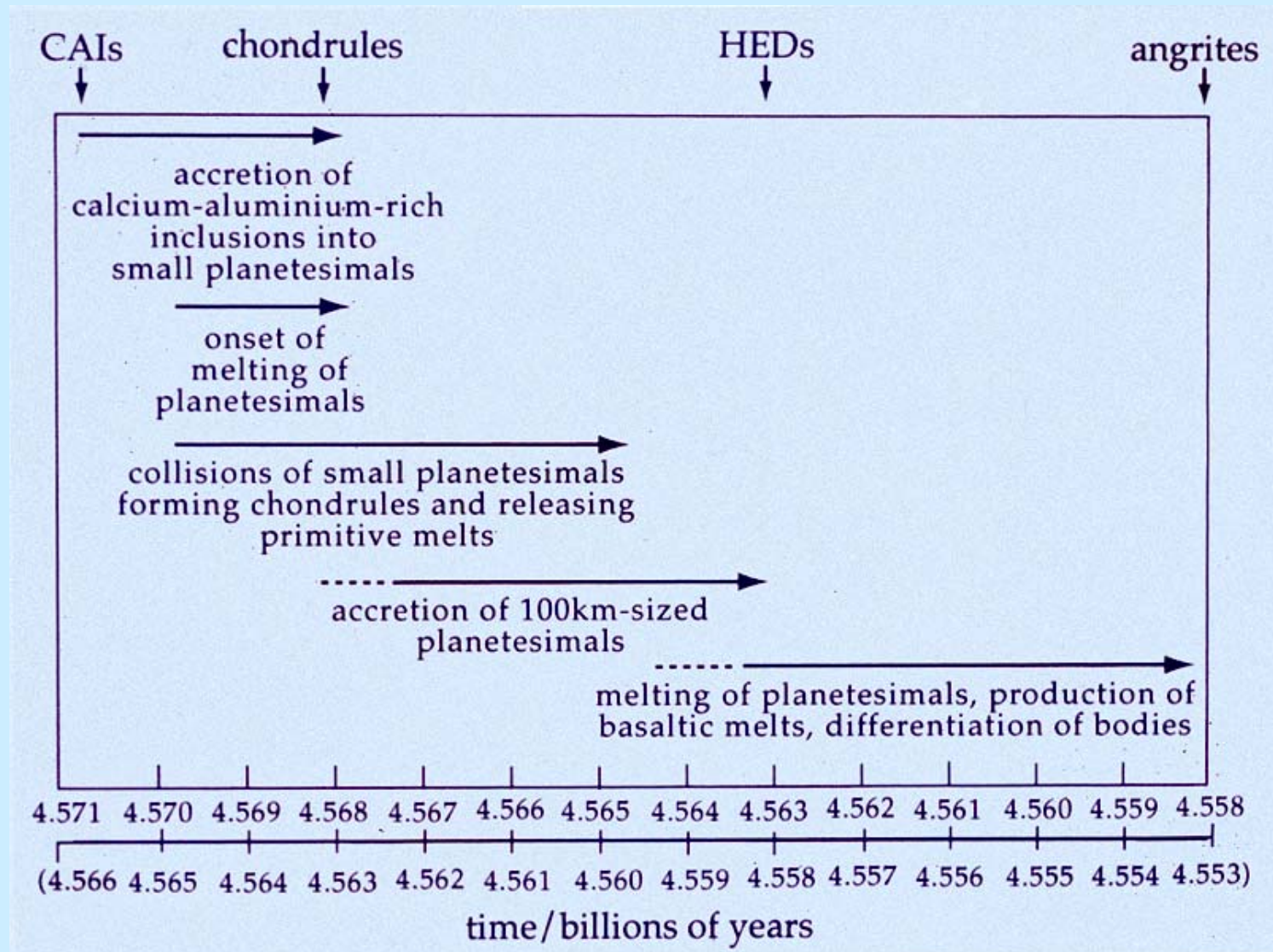


Early nebular timescales

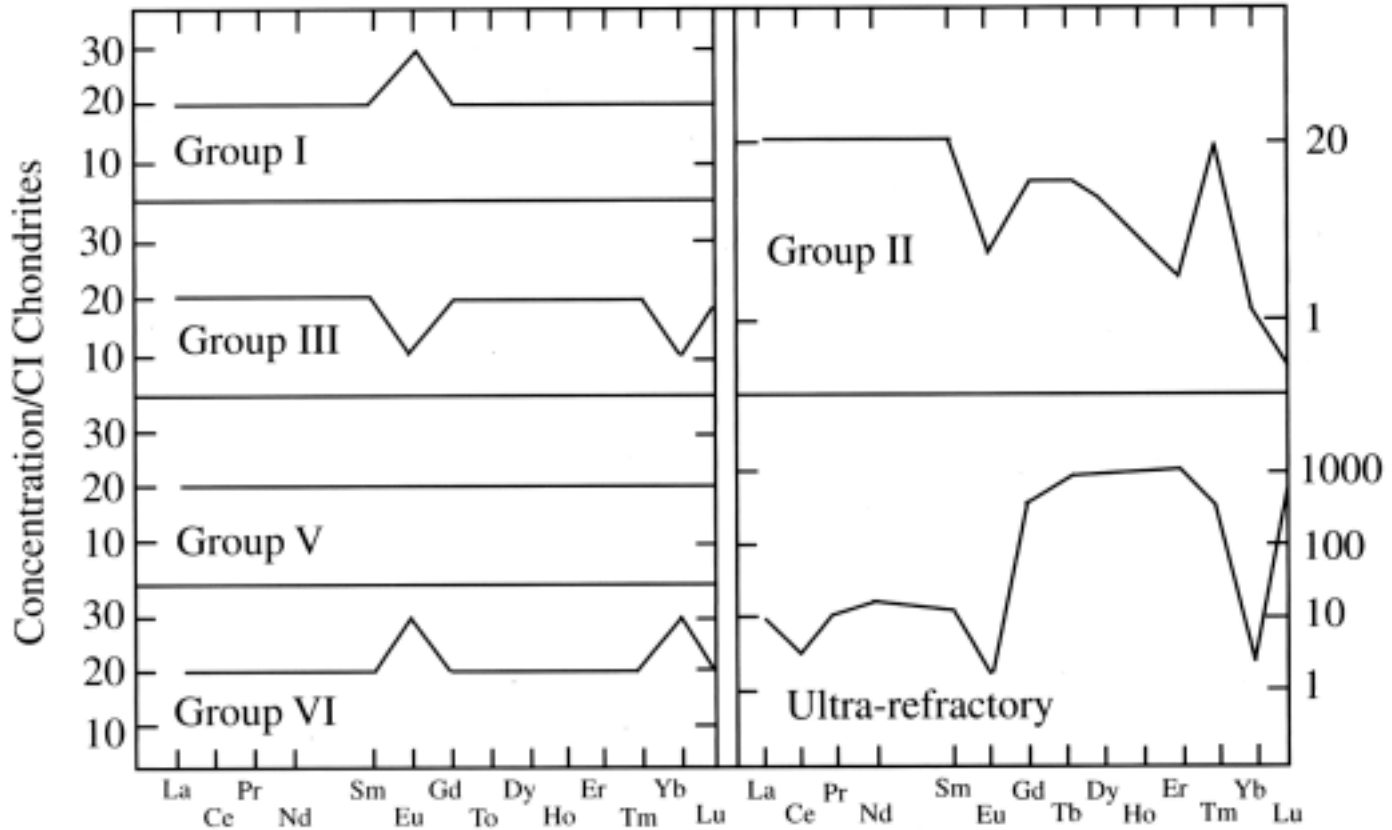
(Wadhwa & Russell)



Early solar system chronology based on ^{53}Mn - ^{53}Cr (Lugmair)

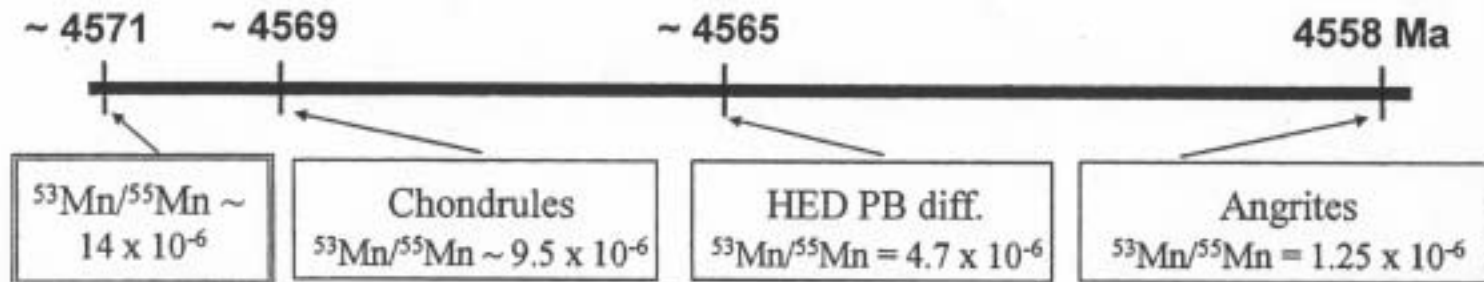


Rare earth element (REE) patterns in CAIs (refractory inclusions)

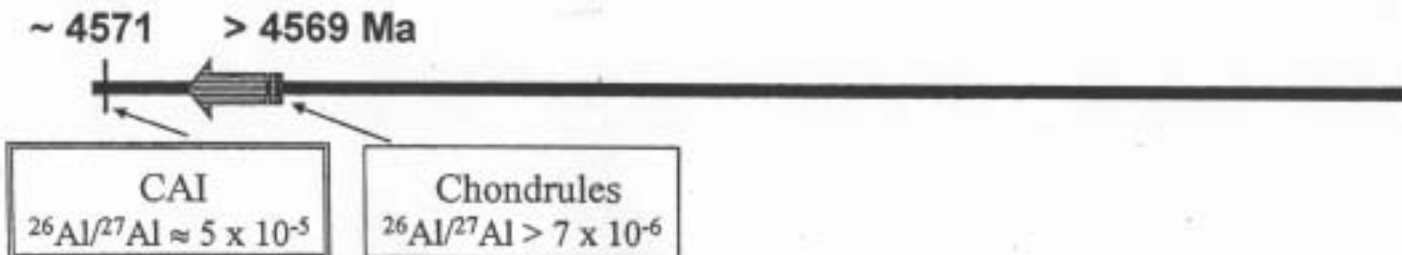


Early Solar System Timelines

Mn – Cr :

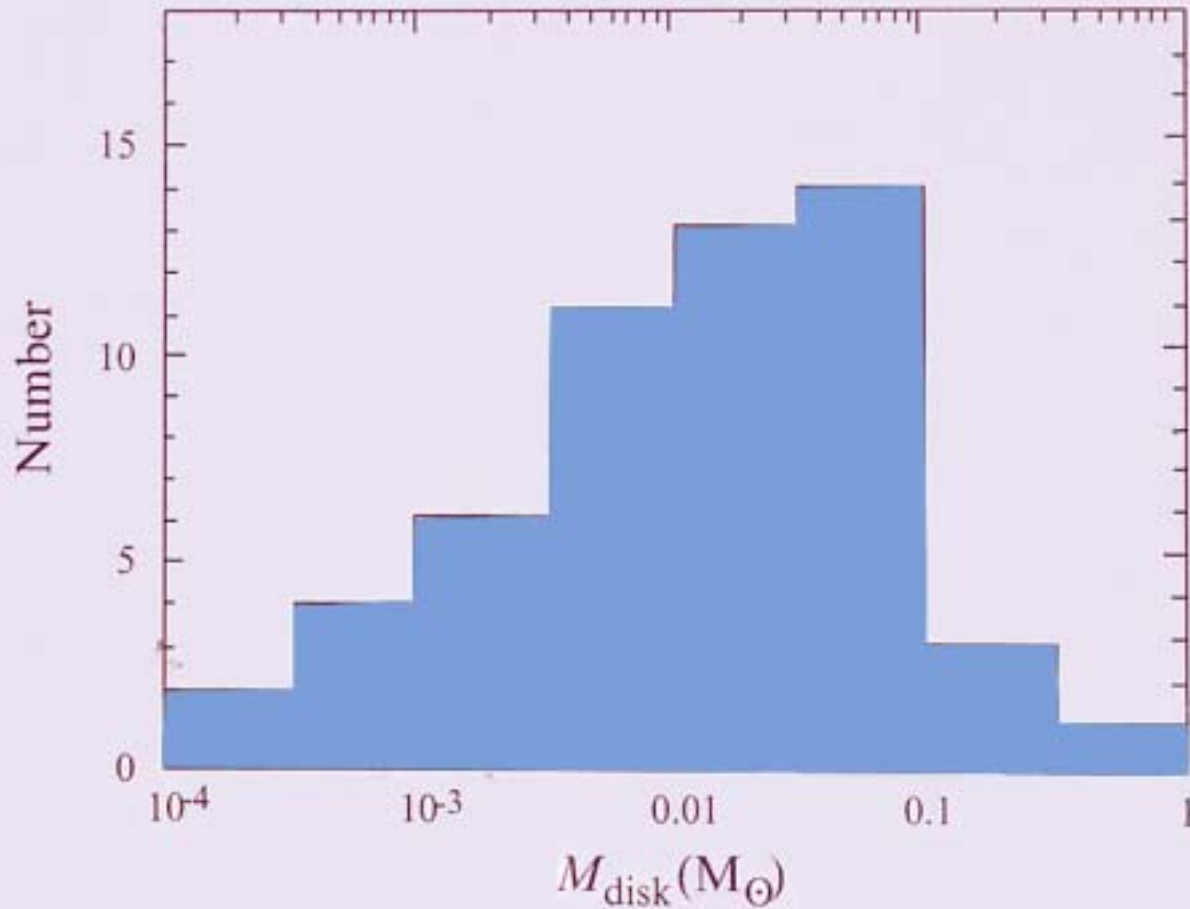


Al – Mg :

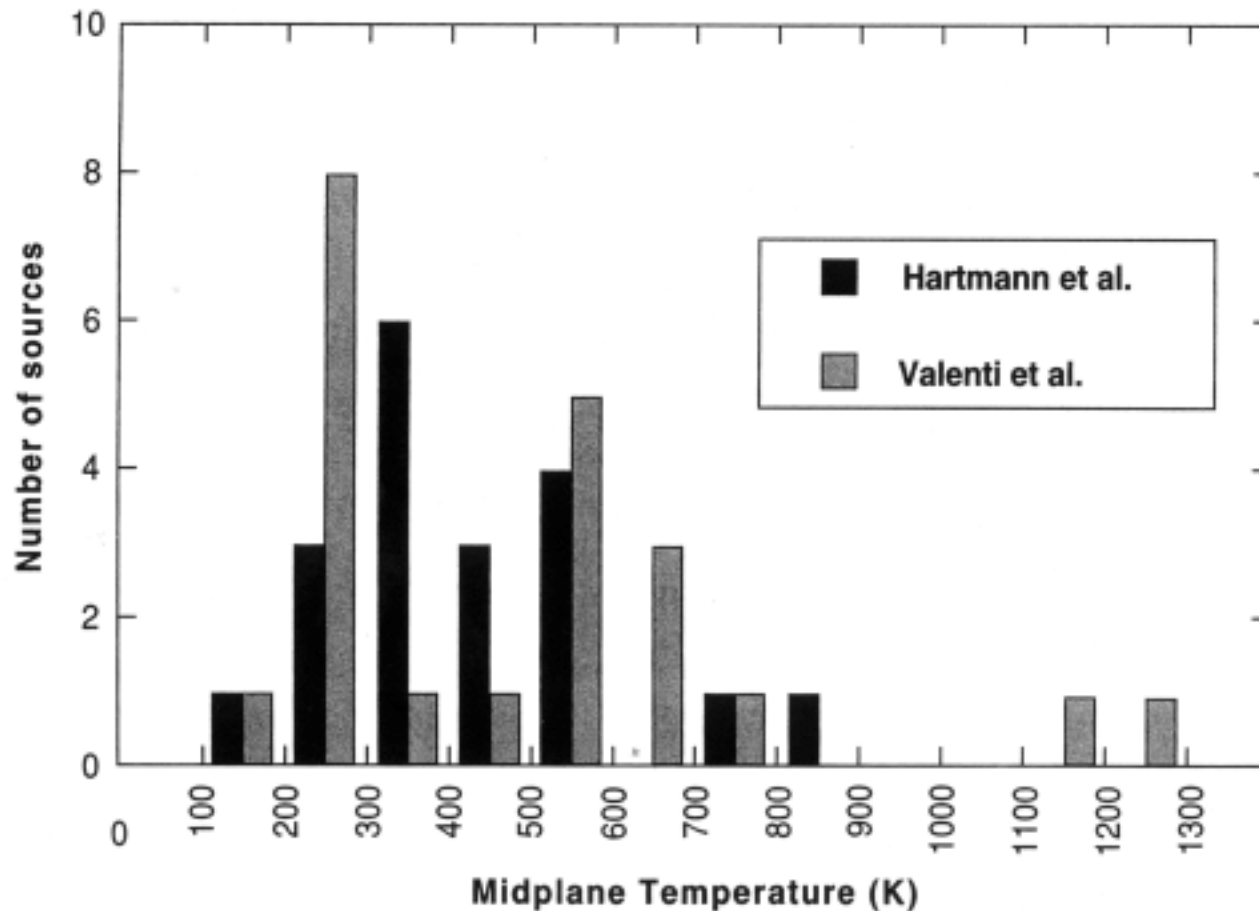


(after Lugmair)

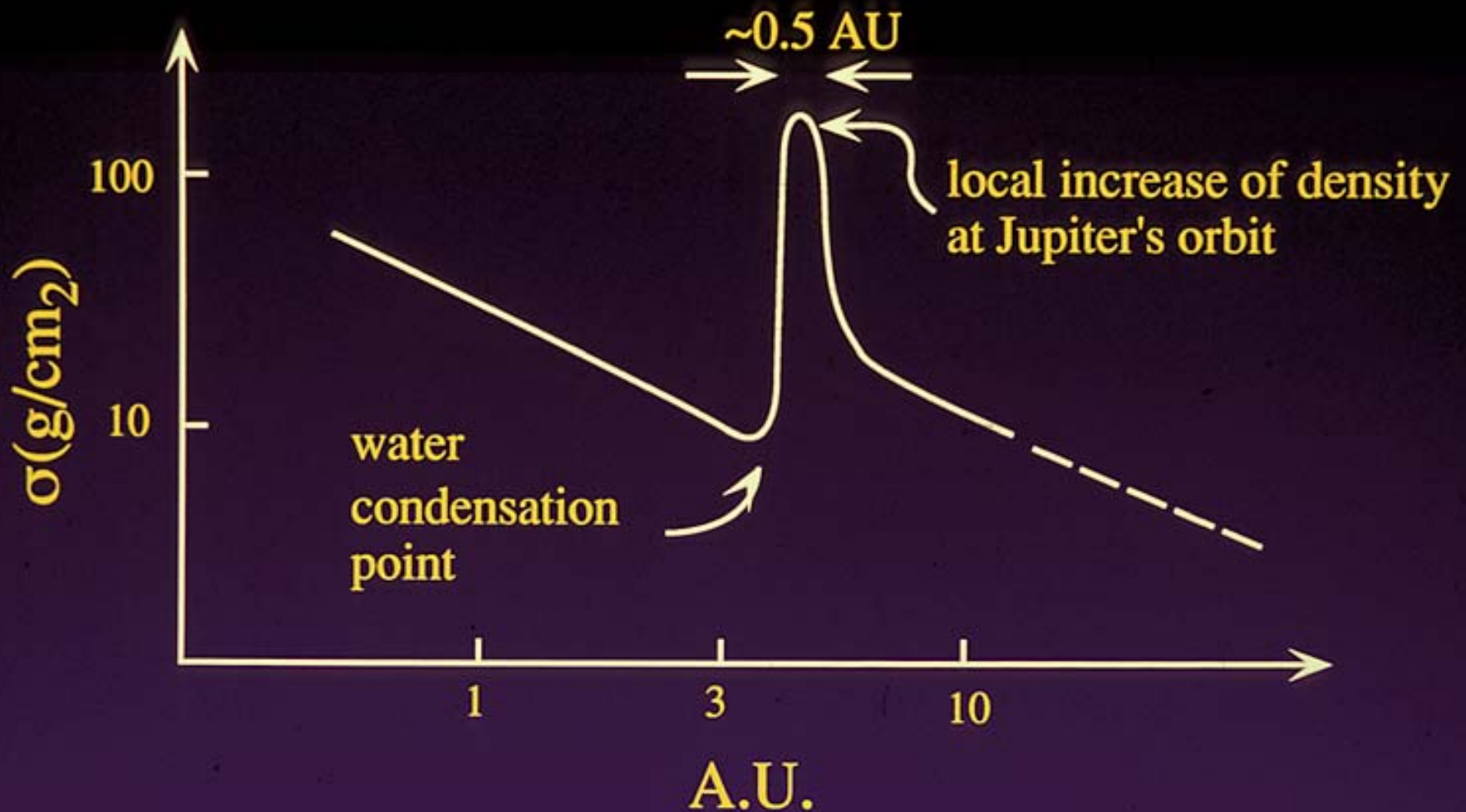
Disk masses around young stars in Taurus and Rho Ophiuchus (Chandler)



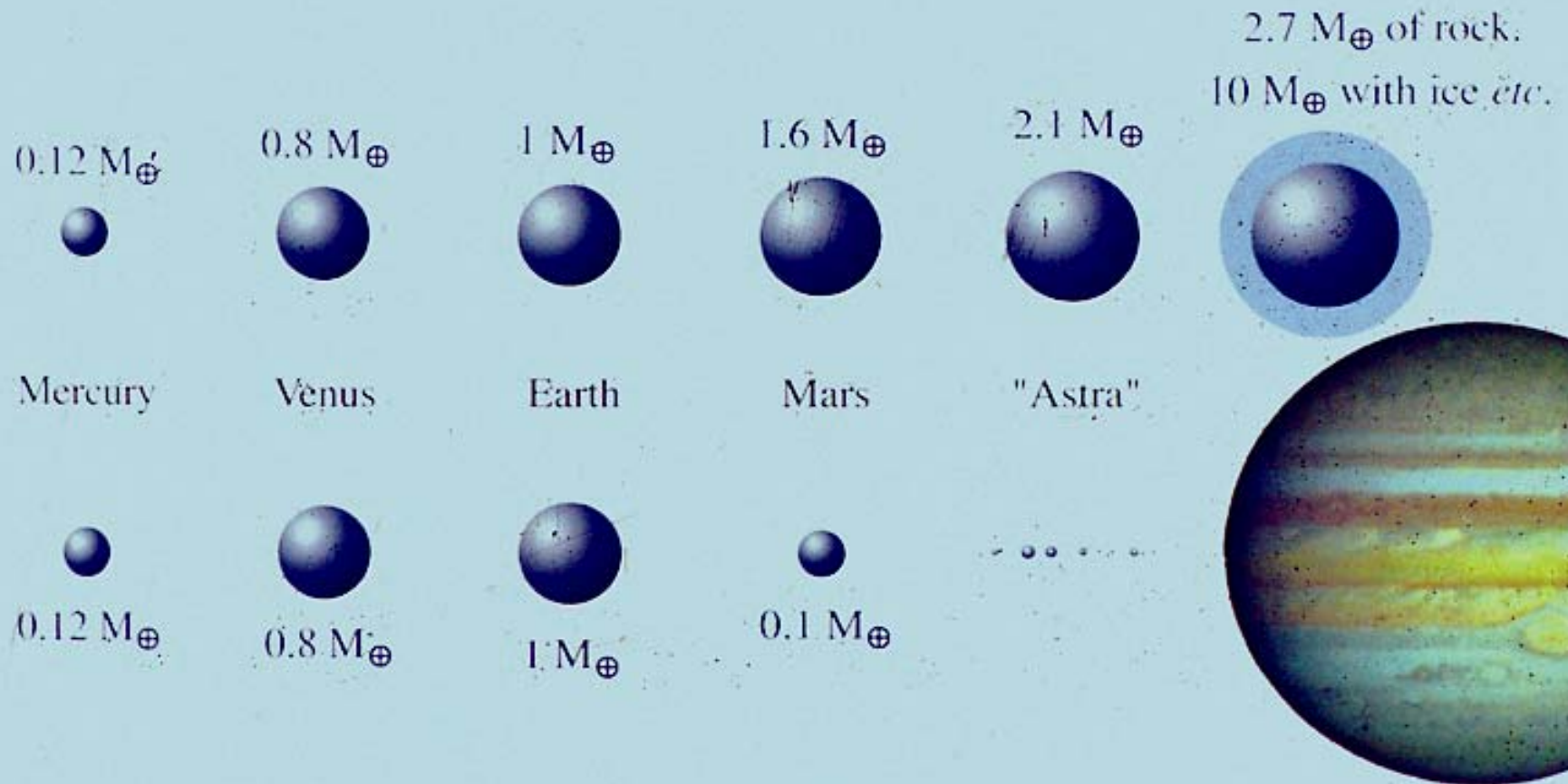
Midplane temperatures (K) in disks around T Tauri stars



Density distribution as a function of distance from a proto-sun (Dave Stevenson)



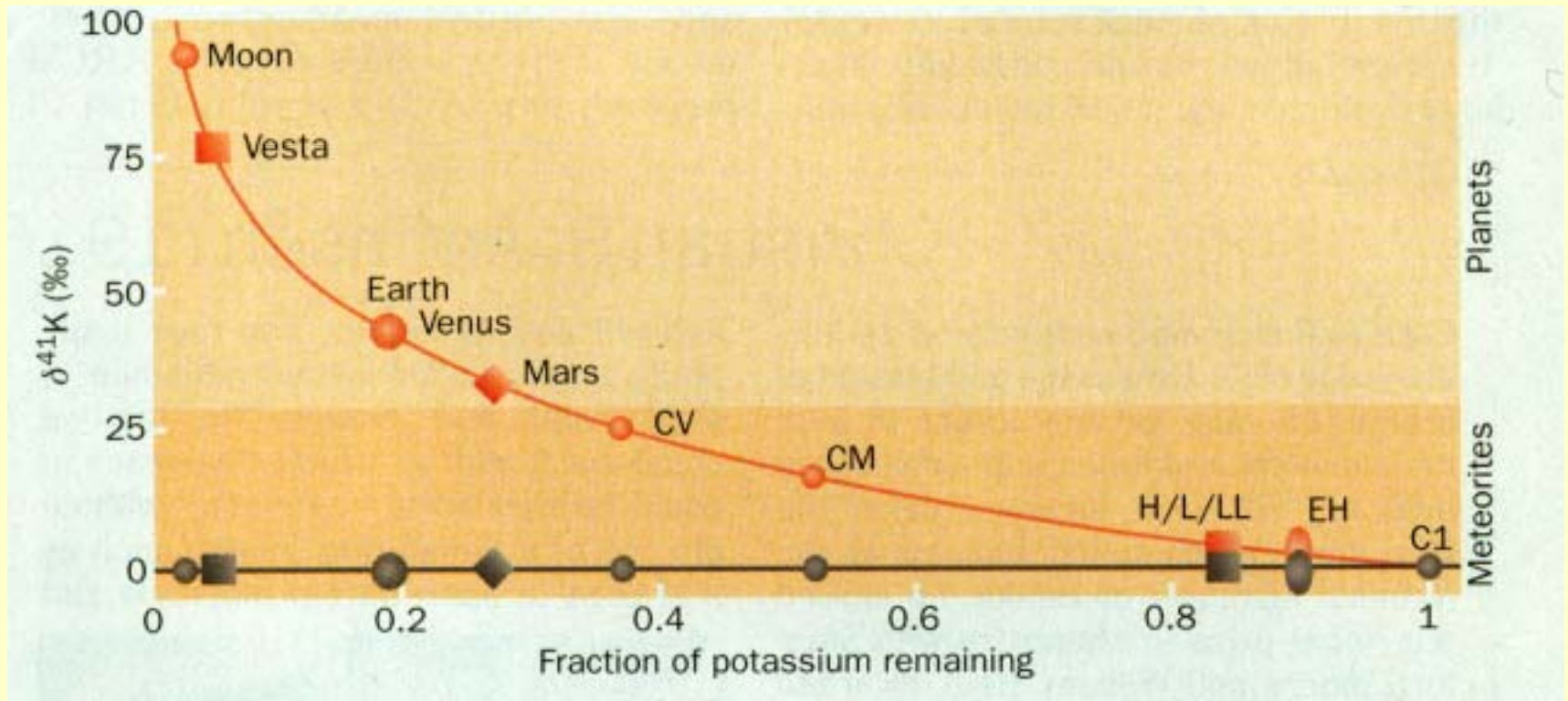
Planet accretion without Jupiter?



Planet accretion in the presence of Jupiter?

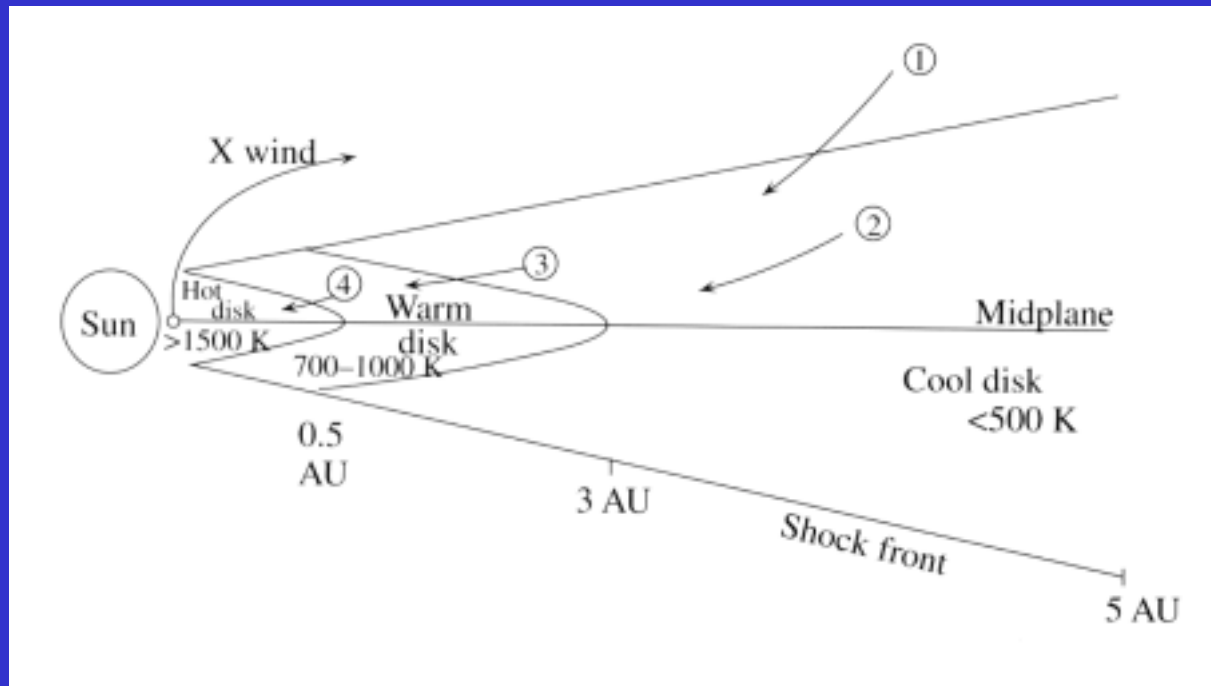
(after John Wood)

Potassium isotopic compositions in the inner solar system (Humayun & Clayton)



bottom line = observed; upper curve = calculated for Rayleigh distillation

A representation of the nebular disk during accretion of the sun.



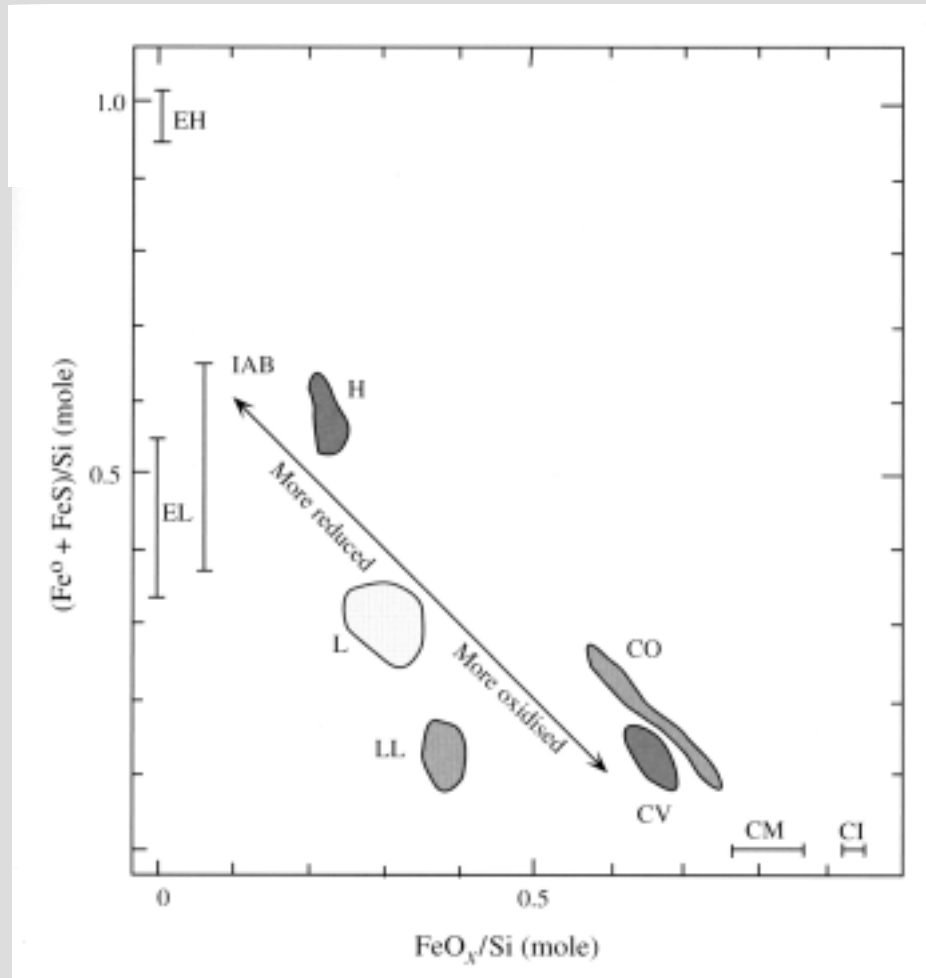
(1) Grains accreting to the cooler outer regions of the disk are (2) transported inwards.

(3) Grains entering the inner warm zones of the disk are selectively vaporized. Refractory olivines and pyroxenes will survive into the central regions but feldspathic grains (containing potassium) will be vaporized. (4) All grains entering the inner region will be vaporized. The hot innermost zone ($> 1800\text{ K}$), the source of the X wind, is a possible site for forming CAIs. The vaporized material will either be accreted to the sun or swept out by T Tauri-type winds. The total vaporization of feldspathic grains can account for the depletion of potassium in the inner nebular without any accompanying isotopic fractionation. (Ed Young)

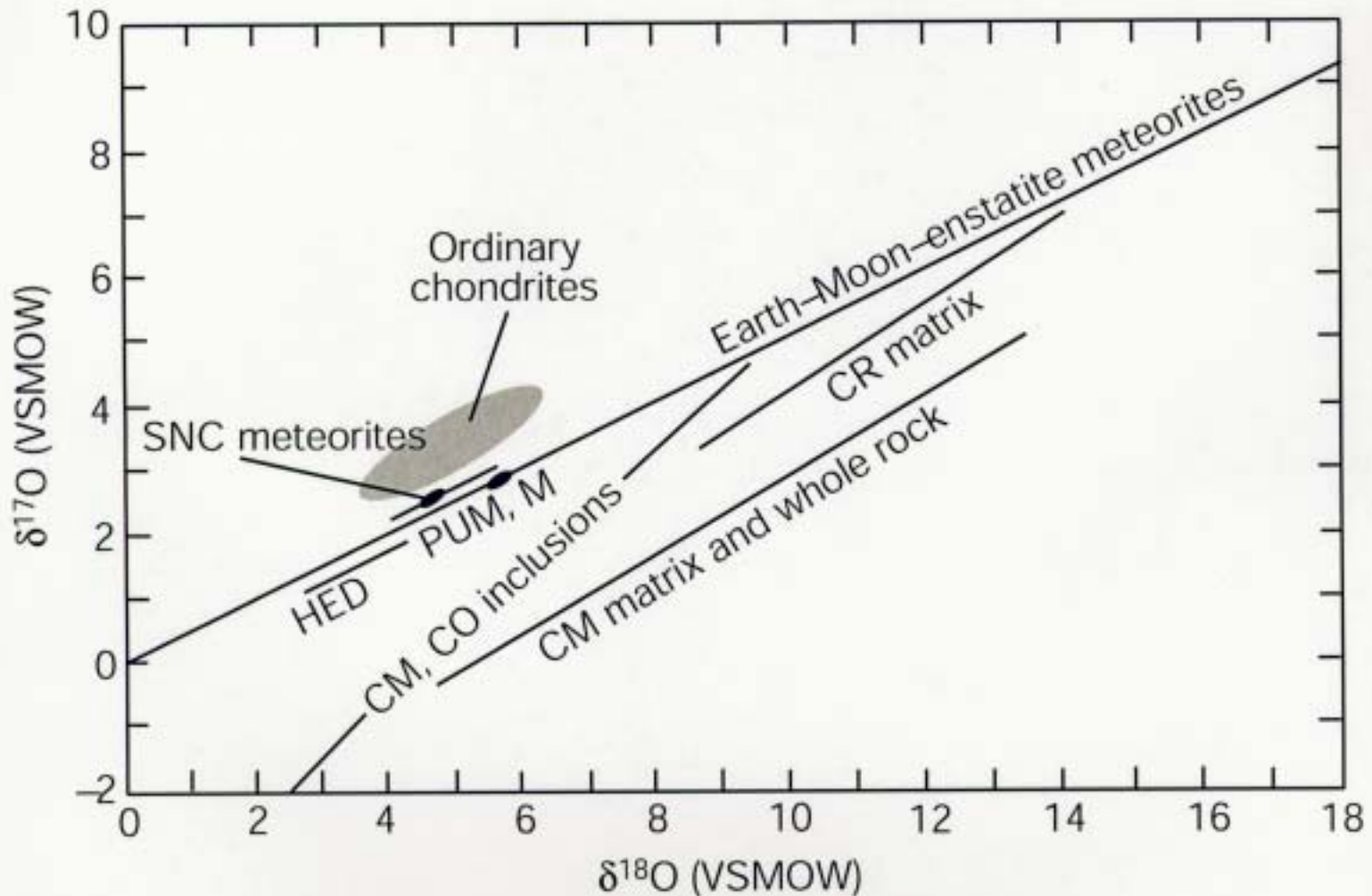


S-type asteroid Ida
(56 x 24 x 21 km)

Variation in oxidised and reduced iron in chondritic meteorites

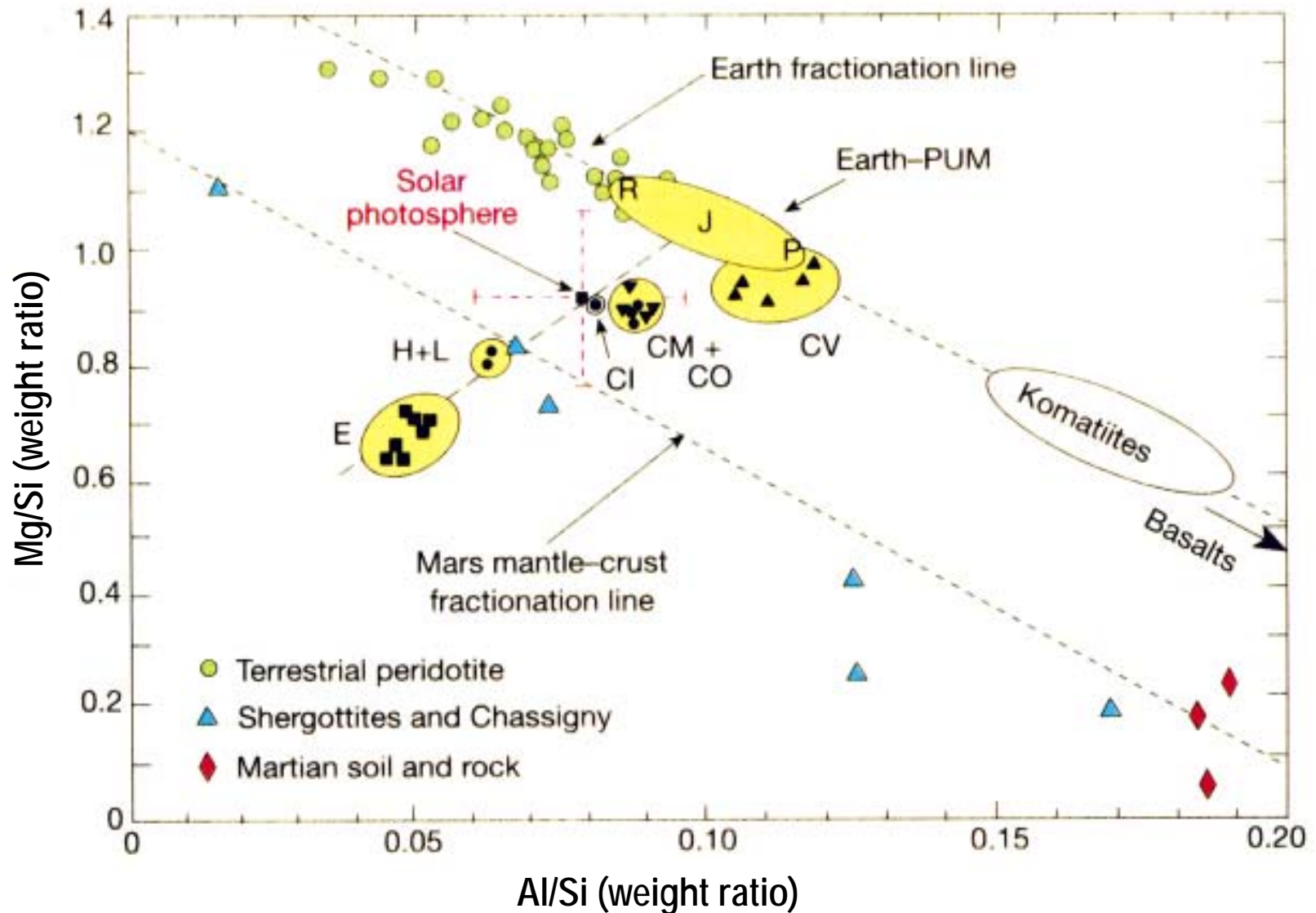


Oxygen isotope variations in the inner nebula (Clayton)

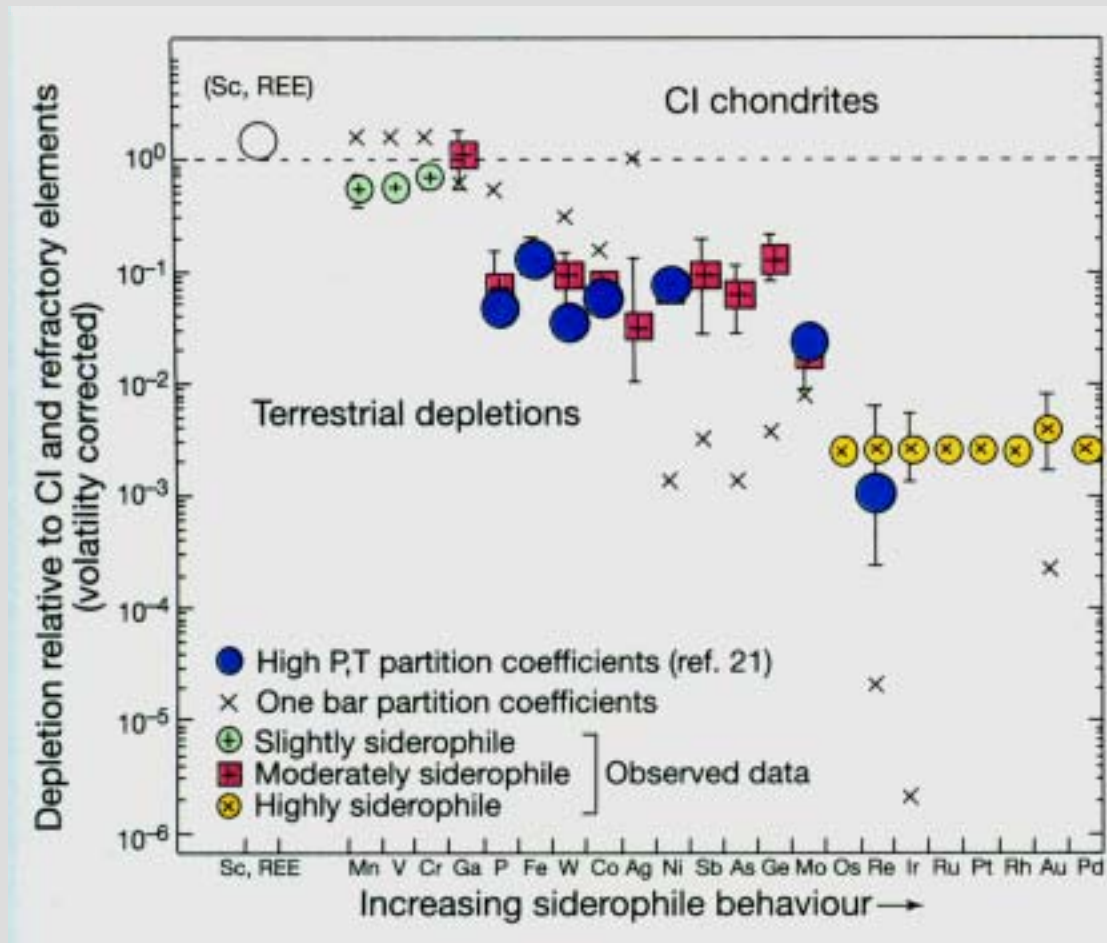


Variation in major elements in meteorites, Mars (?) and Earth

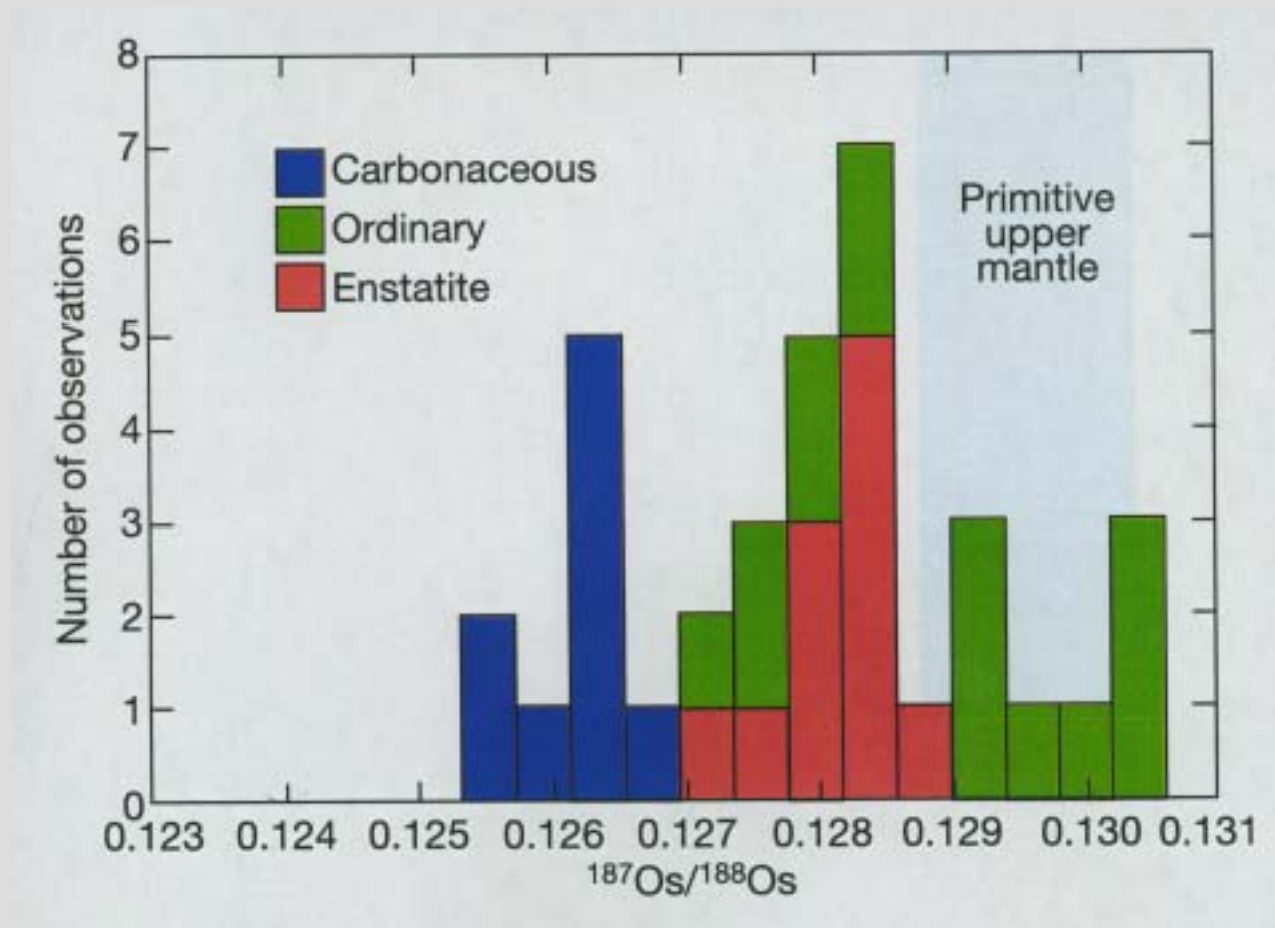
(Wänke, Palme, Righter and Drake)

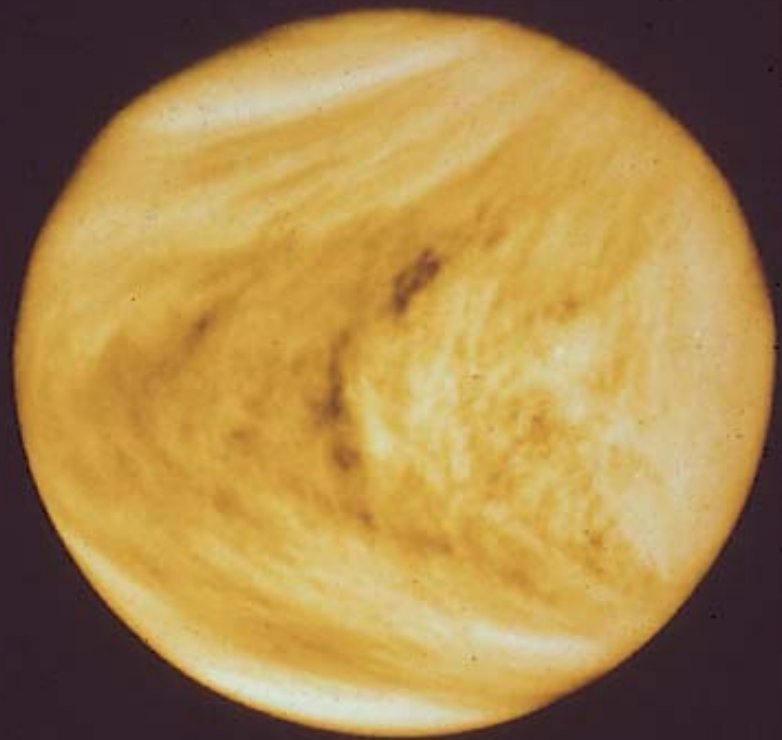


Abundance of siderophile elements in the terrestrial upper mantle



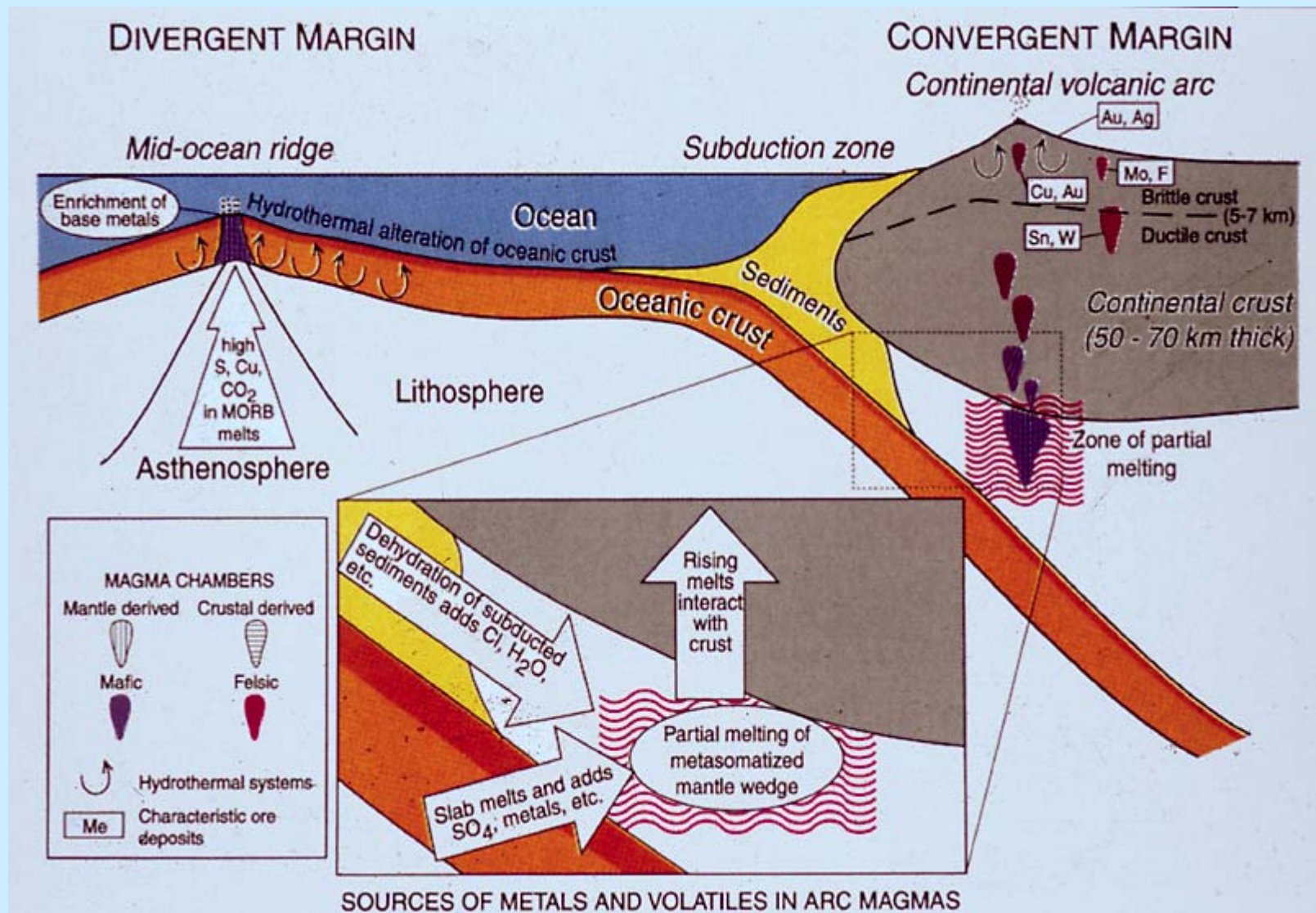
Osmium isotope ratios (^{187}Re - ^{187}Os) in meteorites and the terrestrial upper mantle



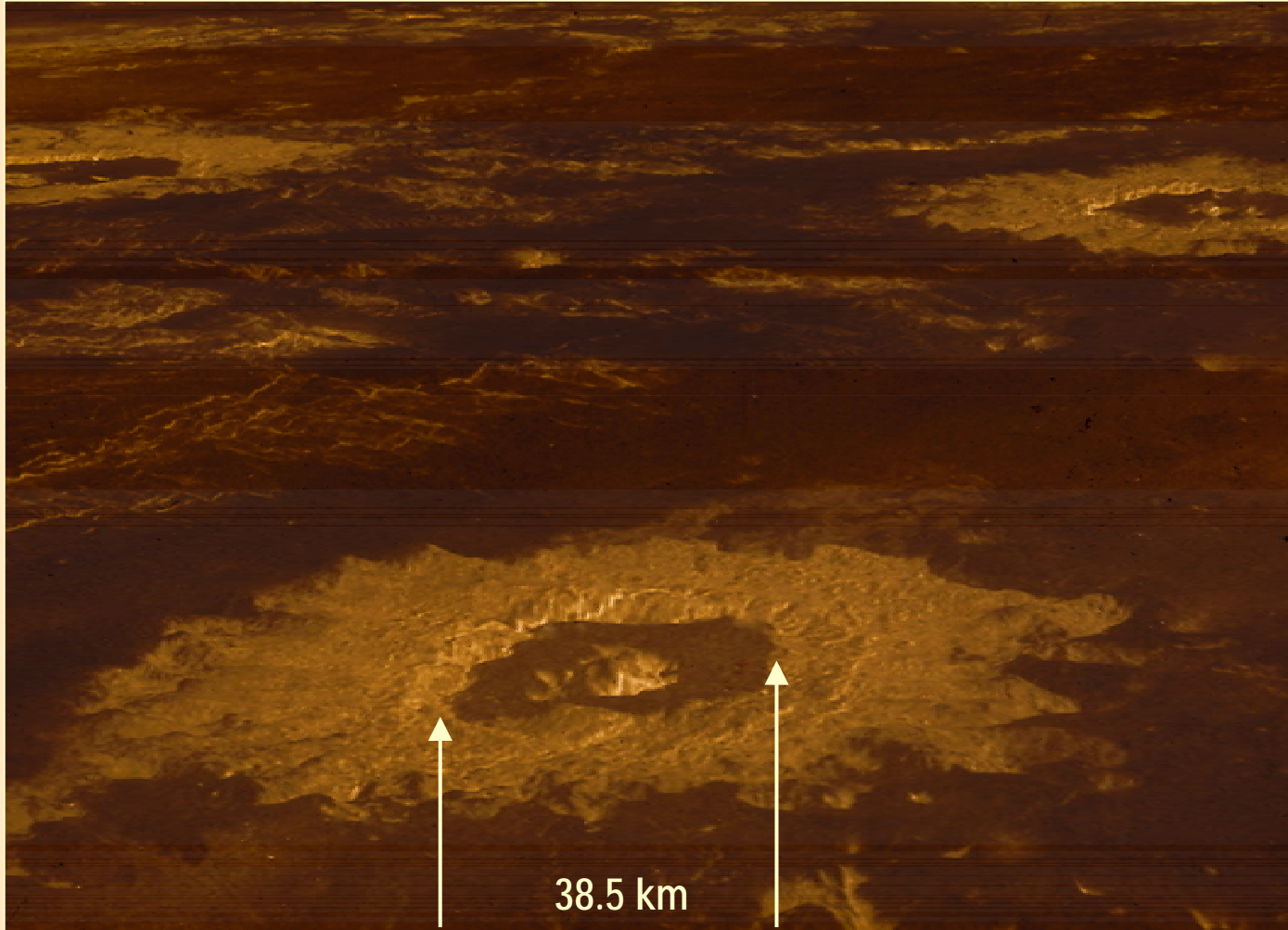


Earth and Venus at the same scale

TERRESTRIAL PLATE TECTONICS

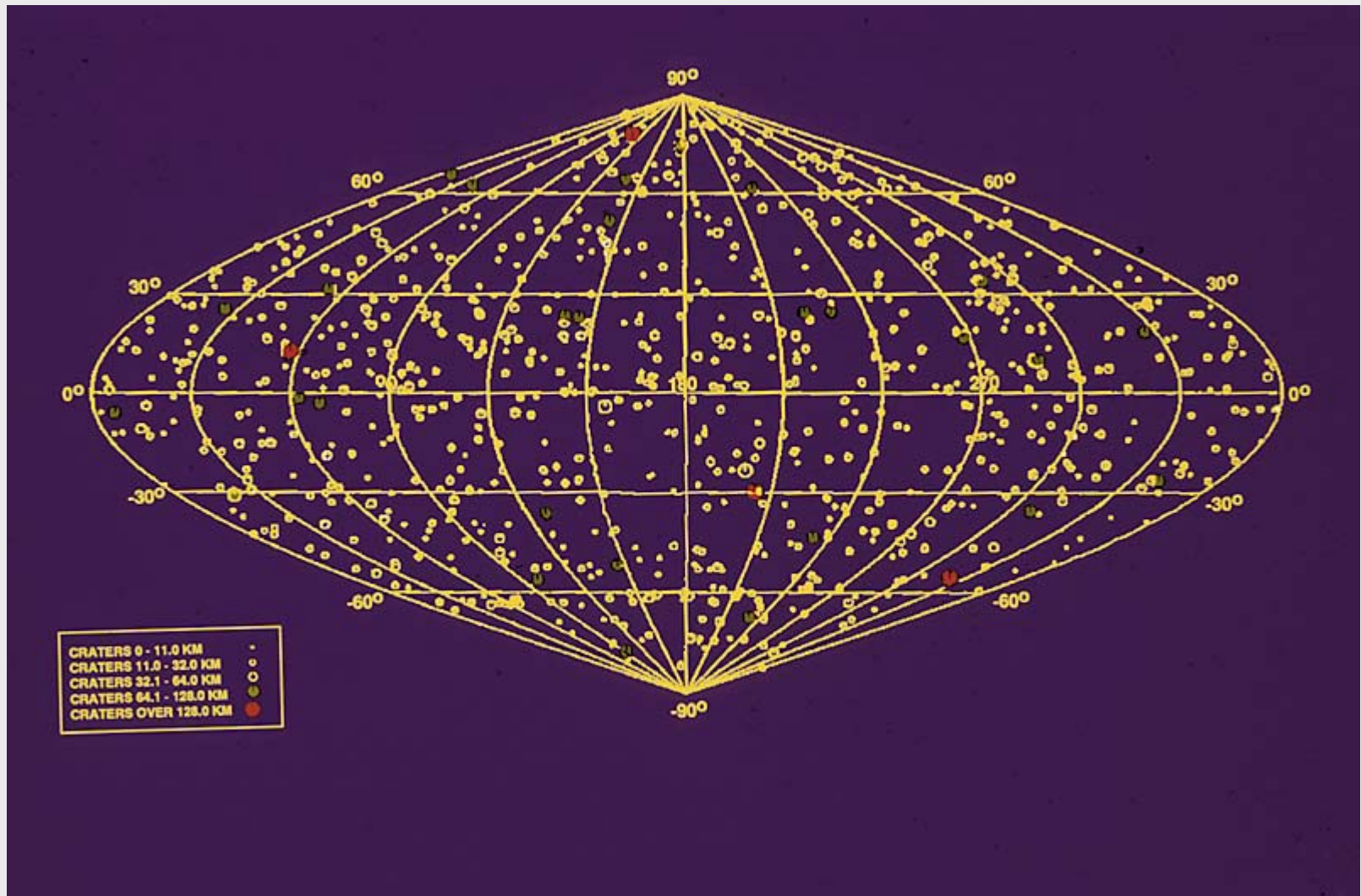


Julia Ward Howe Crater on Venus



Distribution of impact craters on Venus

(Bill McKinnon)



RAPHAEL es Jekyll

RAPHAEL es Hyde

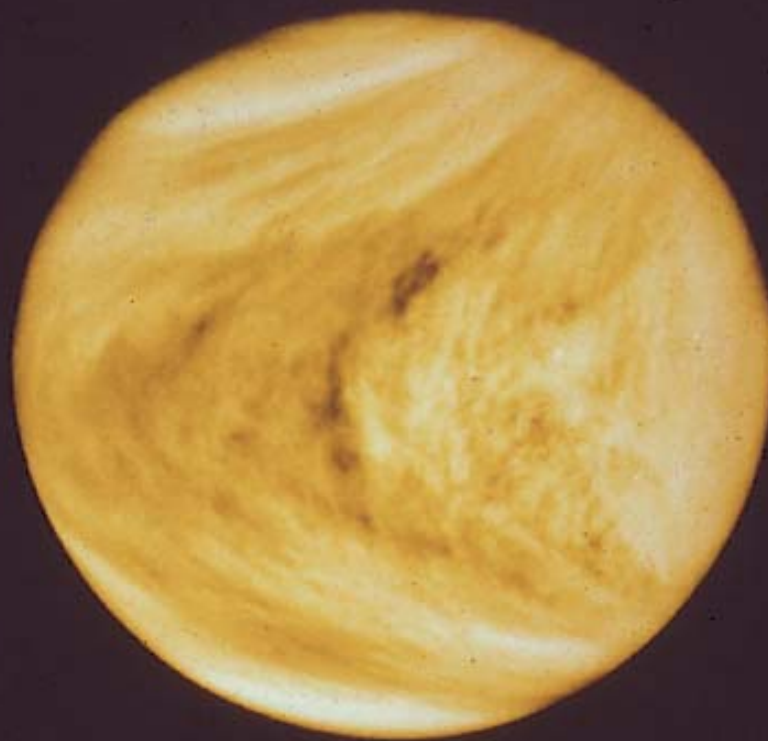
en

Jekyll & HYDE

Una producción de
LUIS RAMIREZ



Highlights del
Musical Original
en Castellano

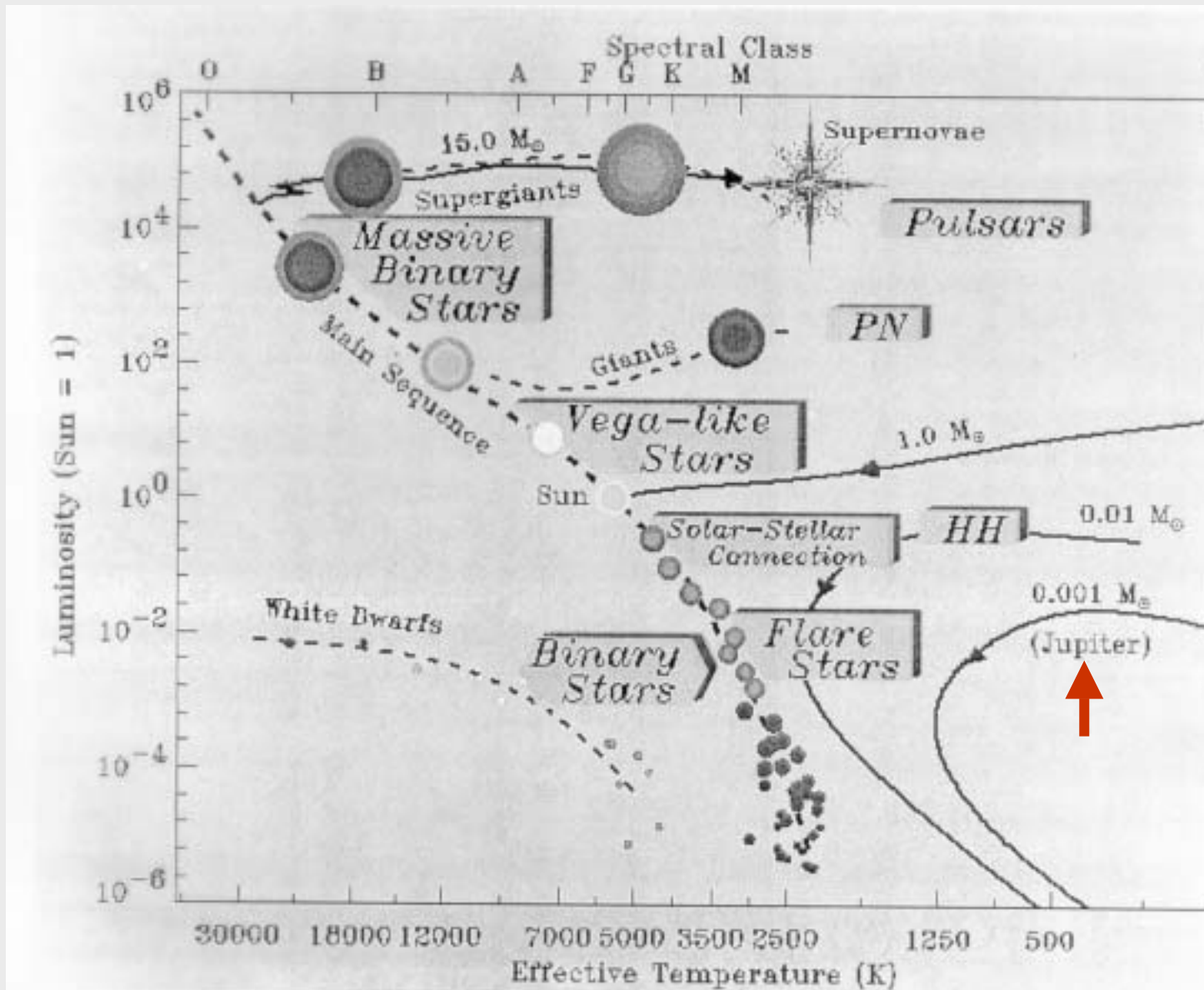


Earth and Venus at the same scale

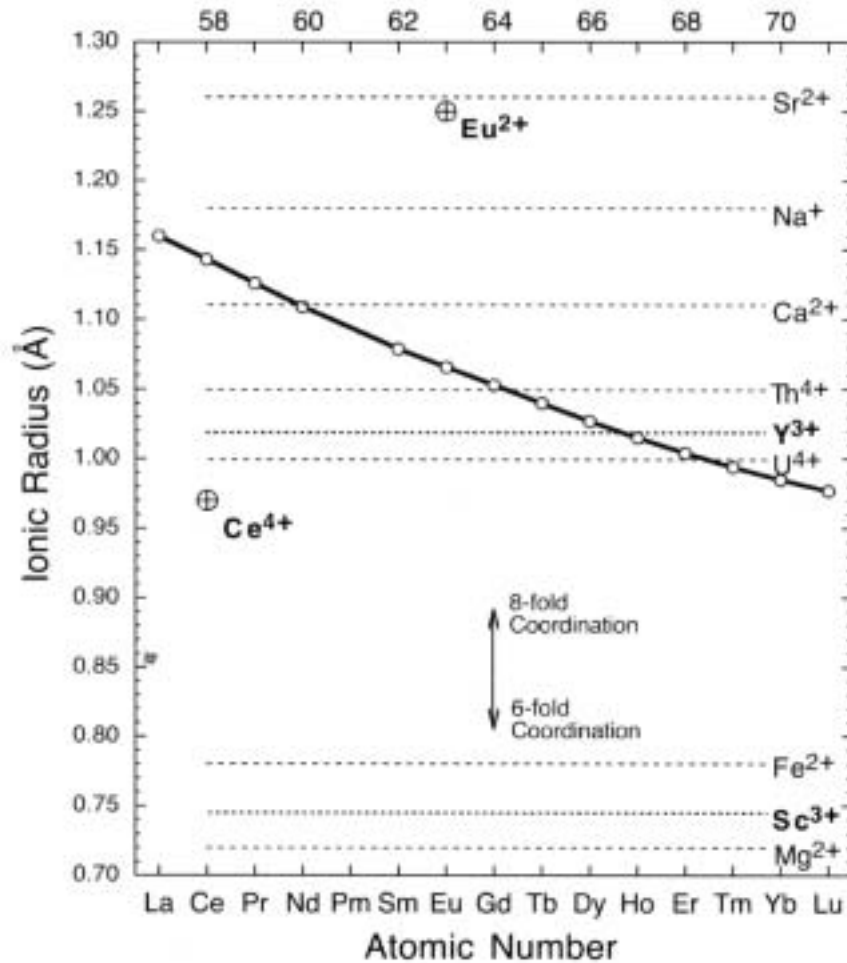
There are indeed few chances that [conditions for life]
would be found united in any globe.
Nature has consequently had to form a great number of
worlds for one habitable milieu to be produced.

Hervré Faye (1885)
Sûr l'origine due Monde (2nd ed) Paris, pp 299 - 300

Hertzsprung-Russell Diagram



Rare earth element ionic radii



On the possibility of Earth-type habitable planets around 47 UMa

Manfred Cuntz,^{a,*} Werner von Bloh,^b Christine Bounama,^b and Siegfried Franck^b

^a *Department of Physics, University of Texas at Arlington, Box 19059, Arlington, TX 76019, USA*

^b *Potsdam Institute for Climate Impact Research (PIK), P.O. Box 601203, D-14412 Potsdam, Germany*

Received 23 June 2002; revised 16 October 2002

Let us emphasize that we assume an Earth-like planet with plate tectonics, a crucial ingredient for our models.

we find that Earth-type habitable planets around 47 UMa are in principle possible!

Short-lived, Now Extinct Radioisotopes
for which evidence has been found in Meteorites

Radioisotope	Half-life (million years)	Daughter isotope	Reference isotope	Initial ratio
^{41}Ca	0.10	^{41}K	^{40}Ca	1.5×10^{-8}
^{26}Al	0.73	^{26}Mg	^{27}Al	5×10^{-5}
^{10}Be	1.5	^{10}B	^2Be	$\sim 5 \times 10^4$
^{60}Fe	1.5	^{60}Ni	^{56}Fe	$\sim 10^{-6}$
^{53}Mn	3.7	^{53}Cr	^{55}Mn	$\sim 10^{-5}$
^{107}Pd	6.5	^{107}Ag	^{108}Pd	4.5×10^{-5}
^{182}Hf	9	^{182}W	^{180}Hf	10^{-4}
^{129}I	16	^{129}Xe	^{127}I	10^{-4}
^{244}Pu	81	Fission Xe	^{238}U	$(4-7) \times 10^{-3}$
^{146}Sm	103	^{142}Nd	^{144}Sm	$(5-15) \times 10^{-3}$